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# The Maxwellian optics laboratory automation using a personal computer

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The Maxwellian optical system described here is fully automated in both experimental control for psychophysical instrumentation and data gathering using a personal computer (PC) with simple interfacing and input/output processing. The system features PC-based high-speed noise-free liquid-crystal shutter control, automated light control, glow modulator tube control, and filter/wedge control. PC-based data gathering and data transfer to the mainframe via RS-232C-based Telocom are described.

The Maxwellian-view optical system for presenting a visual stimulus is an apparatus by which an observer can increase the quantity of achromatic/monochromatic light reaching the retina of an observer. The system, of course, is widely used in vision research laboratories (see Westheimer, 1966).

Problems involved in using the classical Maxwellian optics include noise from mechanical shutter operation, difficulty of precise light control, and manual operation of stimulus pattern change. A noise-free and high-speed shutter is important for visual experiments testing the effects of flash duration and subsequent visual evoked potentials (VEP) (see Osaka, 1984). A personal-computer (PC)-based light control and automated stimulus changer is critical for experimental control.

A PC-controlled noise-free liquid-crystal shutter (LCS) is one solution to the problem of noise and speed of response (maximum of approximately 5 msec), since a LCS has no mechanical structure. A PC-based optical system can also solve some of the remaining problems. Control of the duration of pulsed light, light control by neutral density filter/wedge, luminance calibration, wavelength control, and data acquisition with the Maxwellian optics appear relatively easy and inexpensive using low-cost PCs.

A low-cost PC (e.g., Commodore's PET/CBM, VIC-20, NEC's PC9801, 8801, or Fujitsu's FM-8, FM-11 PCs) provides a relatively inexpensive means of controlling vision experiments (Osaka, 1983b) and data acquisition/analysis, and even serves as a Telecom terminal emulator (Osaka, 1983a). A diagram of the Maxwellian optical system is shown in Figure 1. Any kind of PC incorporating a bit-addressable parallel input/output port, general-purpose interface bus (GPIB), and RS-

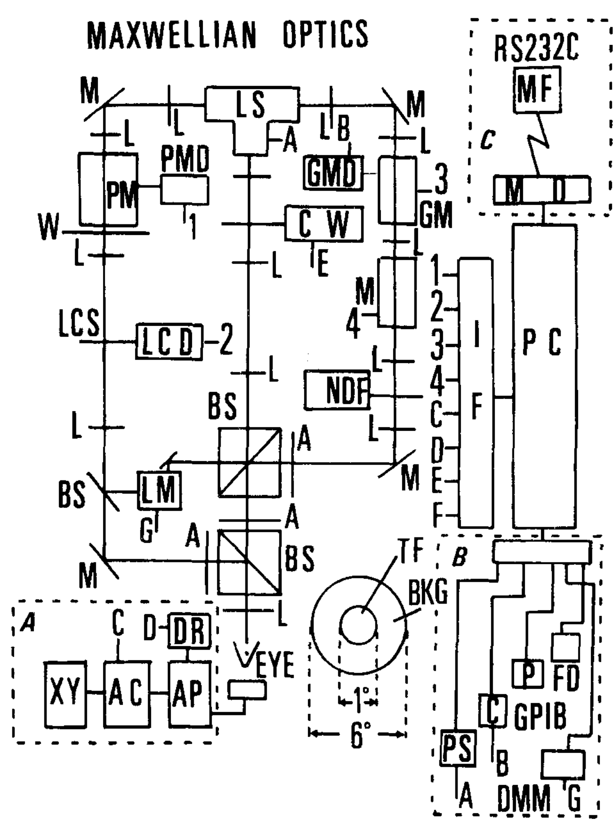


**Figure 1. PC-controlled Maxwellian optical system. LS: light source; GM: glow modulator tube (R1131C); GMD: glow modulator driver; L: lens; M: mirror; PM: pulse motor; PMD: pulse motor driver; PS: power supply; C: counter; P: printer; FD: floppy disk; W: wheel; MF: mainframe computer; LCS: liquid-crystal shutter; LCD: liquid-crystal driver; BS: beam splitter; A: aperture; CW: circular wedge; M: monochromator; NDF: neutral density filter; DR: data recorder; AC: averaging computer (ATAC-450); PC: personal computer; AP: amplifier; XY: X-Y plotter; MD: modem; DMM: digital multimeter; LM: luminance meter; TF: test field; BKG: background view. The dashed areas A, B, and C indicate VEP-, GPIB-, and RS-232C-laboratory, respectively.**

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232C serial communication interface is applicable for the system controller PC.

## A BIT-ADDRESSABLE I/O PORT

A one-chip programmable integrated large-scale circuit (LSI) makes design of psychophysical instrumentation, such as Maxwellian optics, simple and inexpensive for real-time research. One can easily build an intelligent parallel communication interface with little electronics knowledge by using a one-chip peripheral versatile interface adaptor (VIA) coupled with a one-chip Darlington switch (Osaka, 1981). Furthermore, a researcher can easily control the I/0 ports by simply putting a bit pattern on the control registers. Programming for I/O processing is also simple by using PEEKing/POKEing at each I/O register address (Osaka, 1979a, 1979b, 1980).

This type of a bit-addressable I/O register controls the LCS (Nitten Corporation), pulse motor (PM; Nippon Pulse Motor Corporation, PA62), glow modulator (GM) tybe (Sylvania Corporation, R1131C), monochromator (M; Jobin-Yvon, H20 with I/O slit width of 1 mm), and circular neutral density wedge (CW; Kodak, A6020).

The LCS can be activated by an LC driver (LCD; 99 V dc) with a TTL-level trigger pulse input: The duration of the shutter operation can be controlled by the pulse width given by the PC. Figure 2 shows an example program for LCS control. The LCS has rise and fall times shorter than 4.5 msec which enables high-speed shutter control without mechanical noise. GM tube control can be achieved by providing a pulse on the trigger gate of the GM tube driver (GMD) (Osaka, 1979a). Furthermore, the monochromator (M) and the stimulus wheel (see Osaka, 1979a) connected to the associated pulse motor can be controlled by supplying a pulse to the pulse motor driver (PMD): A pulse rotates the associated axis of the monochromator (M) for a 6° step angle. Similarly, a pulse rotates the pulse motor for a 15° step angle; thus, 24 pulses result in one rotation (360°) of an associated stimulus wheel (Osaka, 1979a).

A bit-addressable I/O port also controls the averaging computer (AC; Nihon Kohden Corporation, ATAC-450) and data recorder (TEAC Corporation, R250).

## GPIB-BASED SUBSYSTEM

Spot luminance meter (Minolta, 1° digital) continuously measures the light output in order to maintain the amount of light at a constant luminance level that is predetermined and stored in the PC program (Osaka, 1982). The PC reads the analog-to-digital converted luminance value from the GPIB-driven digital multimeter (DMM; Takeda Riken Corporation, TR6841) connected to the luminance meter and compares it with a predetermined level. If the difference between the previously stored and the measured value is greater (less) than some permissible value, say, 2 cd/m², the PC adjusts the luminance level by rotating the CW until both values coincide. This feedback looping can be done by a BASIC program using a conditional "IF ... THEN" statement (Figure 2). This looping has merit in detecting a small deviation of the light. Figure 2 shows an example program for light control. Our simple GPIB-based laboratory system includes (Fisher & Jensen, 1980; Osaka, 1983b): The power supply (PS; Takasago Corporation, TC801), digital counter (C; Takeda Riken Corporation, TR5822), tractor printer (P; Commodore Corporation, CBM3022), and floppy disk (FD; Commodore Corporation, CBM3040), all connected to the PC. (Refer to Figure 1, dotted line area B, at the lower right portion of the figure.)

## VEP LABORATORY SECTION

The VEP averaging processor (AC; Nihon Kohden Corporation, ATAC-450 system) receives an amplified electroencephalogram from the observer's electrodes at oc-

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100 rem liquid crystal shutter control
110 x=59459:y=59471:rem bit-addressable port,pc=pet/cbm
120 poke x,2:poke y,2:a=ti:rem pulse on and time set
130 if ti-a>6 then 150:rem 100 ms timeout
140 goto 130:rem looping
150 poke y,0:rem pulse off
   .
   .
   .
   .
   .
200 rem light control using digital multimeter and cw
210 open 2,8:print#2,"r3":rem dmm open, set 200mv range
220 l=l+1:counter
230 input#2, b(l)
240 if b(l)>150 then 260:rem compare measured and stored value
250 goto 240:rem looping
260 poke x,64:poke y,64:poke y,0:rem rotate circular wedge
270 goto 220
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**Figure 2. Sample BASIC program for LCS and light control.**

cipital positions (dotted-line area A in Figure 1). After 10 min of dark adaptation, the observer is asked to fixate the center of the test field (TF): When the PC triggers the LCS and AC simultaneously, a brief flash without noise appears on the TF, which evokes a visual evoked potential. VEP averaging and its power spectra can be estimated using a Fast Fourier Transformation (FFT) algorithm (Osaka, 1984).

## RS-232C-BASED SUBSYSTEM

The RS-232C-based communication system is shown in Figure 1 (upper right, dotted-line area C). The PC with RS-232C interface capability transfers gathered data to the mainframe computer (MF; Fujitsu M382) via an acoustic coupler (MD; Tamura Corporation, ACTAM360A1). The data gathered during an experiment is stored on floppy disk (FD) and then transferred to the host mainframe in the Data Processing Center, Kyoto University, via TTY-protocols [i.e., 7-bit data length, 1-stop bit, even parity, and 300 bps half-duplex mode (Osaka, 1983a)]. Usually we use Statistical Analysis System (SAS) and SAS/GRAPH statistical packages for further data analysis at the host computer.

## SUMMARY

The LCS works quite well with the PC; however, there appears to be a slight loss in light intensity due to the absorption within a liquid crystal when a beam passes through it. Light control, as well as pulse motor control, works well with the PC.

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